STUDY OF A SINGLE-CHARGED IONS ECR SOURCE MATCHING OF THE EXTRACTED BEAM TO AN ISOTOPE SEPARATOR

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STUDY OF A SINGLE-CHARGED IONS ECR SOURCE MATCHING OF THE EXTRACTED BEAM TO AN ISOTOPE SEPARATOR

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Résumé : - Une nouvelle source ECR a été étudiée pour la production d'ions monochargés. Un régime très stable a été obtenu avec une source d'ions à deux étages identiques en cascade. La puissance RF est fournie à l'aide de deux magnétrons à 2.45 GHZ. La chambre a été réalisée à l'aide de deux tubes coaxiaux de Pyrex, le tube extérieur assurant l'étanchéité au vide et l'isolement électrique. Les tubes sont alignés à l'intérieur de deux cavités multimodes axialement limités par trois bobines magnétiques. Le faisceau d'ions est accéléré à 20 kV et focalisé à l'aide de lentilles électriques. Pour l'argon et le xénon, des courants de 1 mA d'ions monochargés ont été extraits. L'influence des divers paramètres de la source a été étudiée progressivement sur un ensemble comportant un aimant d'analyse de 60° et sur le séparateur d'isotopes 120° en ligne sur l'accélérateur SARA. Les émittances et les images observées ont montré les difficultés rencontrées pour compenser les effets de charge d'espace. Des suggestions et des développements futurs sont proposés pour obtenir des conditions de séparation isotopique convenables.

Abstract : A new ECR ion-source has been designed and studied for single-charged ion beams. A very stable regime has been obtained with an ion-source made of two identical stages in cascade. The RF power supplies consist of two 2.45 GHZ magnetrons. The discharge chamber is made of two coaxial Pyrex tubes. The external one ensures vacuum and HT insulation. The tubes are aligned inside the two multi-mode cavities axially limited by three magnetic coils. The ion beam is extracted at 20 kV and focused with electric lenses. For argon and xenon, 1 mA single-charged ion currents have been extracted. The influence of various parameters has been progressively achieved with a set-up including a 60° analyzing magnet and with the 120° on-line isotope separator at SARA. From emittances and images observed it appears difficult to compensate charge space effects. Suggestions and future developments are proposed to improve qualities of the isotopic separation.

1 - INTRODUCTION

For identification and nuclear structure studies of new exotic nuclei far from stability, an helim-jet coupled on-line mass separator is presently used at SARA. With a medium-current Bernas-Nier ion-source, coupling efficiencies of 1-2 % have been currently reached in the light rare-earth region /1/. In order to improve these efficiency values and to increase the ionization of other radioactive refractory elements, recent developments have been focused on the production of single-charged ions by means of a new ion-source of the ECR-type. After a first optimization of decisive parameters such as geometry, RF frequencies, influence of a radial hexapole, on a small and compact prototype, an ion-source made of two identical stages in cascade, working with 2.45 GHz magnetrons, has been retained /2/. As this device has been presented as a poster at the last International Workshop on E.C.R. ion sources, in November 1987, the present paper gives only a rapid description and reports on some test measurements made with two different separating magnets. Due to the complexity of the experimental results obtained for emittances and separation performances, complementary improvements, as proposed, are needed before the study of the coupling with helium-jet systems.

2 - EXPERIMENTAL

The design reproduced in figure 1 with its main geometrical characteristics is the result of an optimization procedure. A system including two stages in cascade has

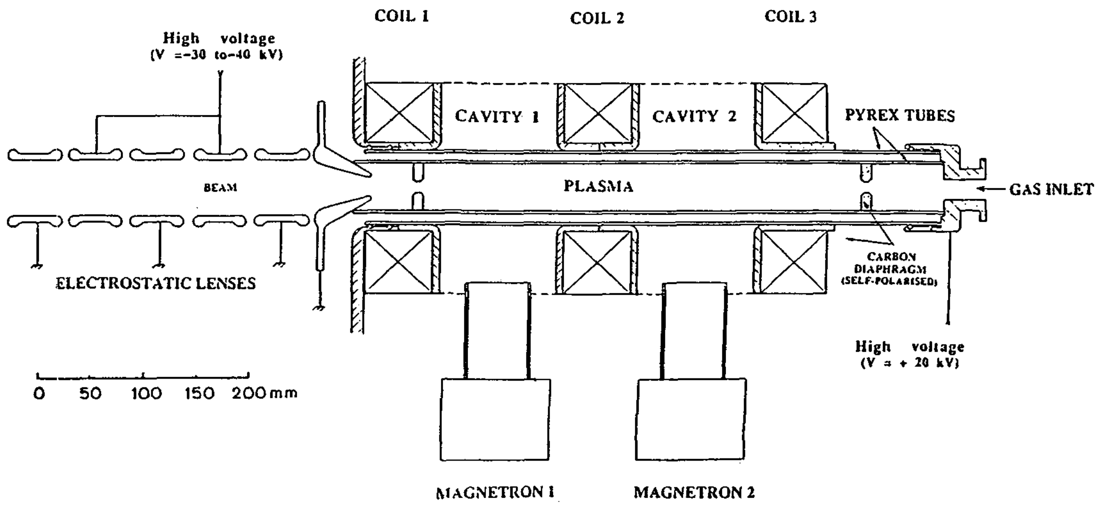

Figure 1 - Layout of the ECR ion-source system.

been retained to keep a stable plasma with respect to the gas pressure. The microwawes are injected from each 2.45 GHz RF frequency magnetron into grided multimode cavities through adjustable metallic waweguides (figure 2). The ion source body consists of an assembly of two coaxial pyrex tubes including graphite discs to avoid the condensation of metals on the chamber walls.

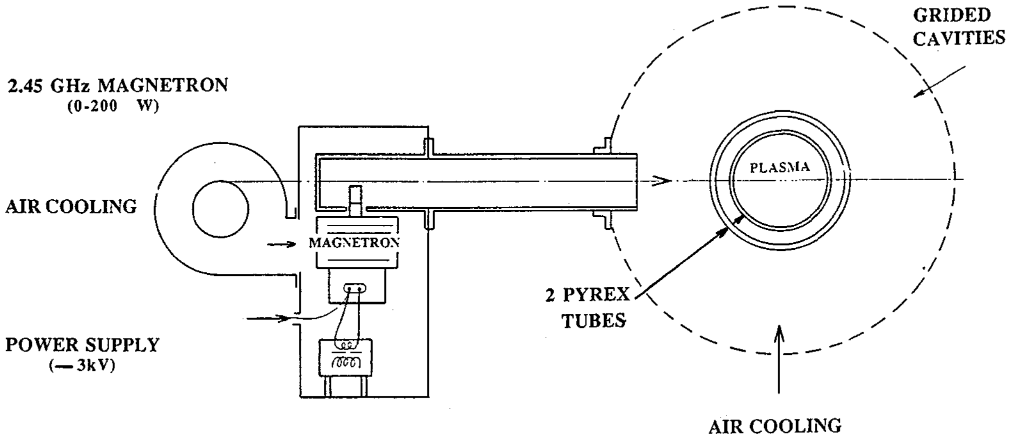

Figure 2 - Schematic drawing of the RF injection

The outer tube defines the vacuum source and improves HT insulation, the plasma being inside the inner tube. The high voltage is applied only to the gas injection system and consequently to the plasma. The extraction is obtained in the range of 20 kV to 30 kV and the ion beam is focused with electrostatic lenses on a collector. Pumping is achieved using diffusion pumps at the source entrance and at

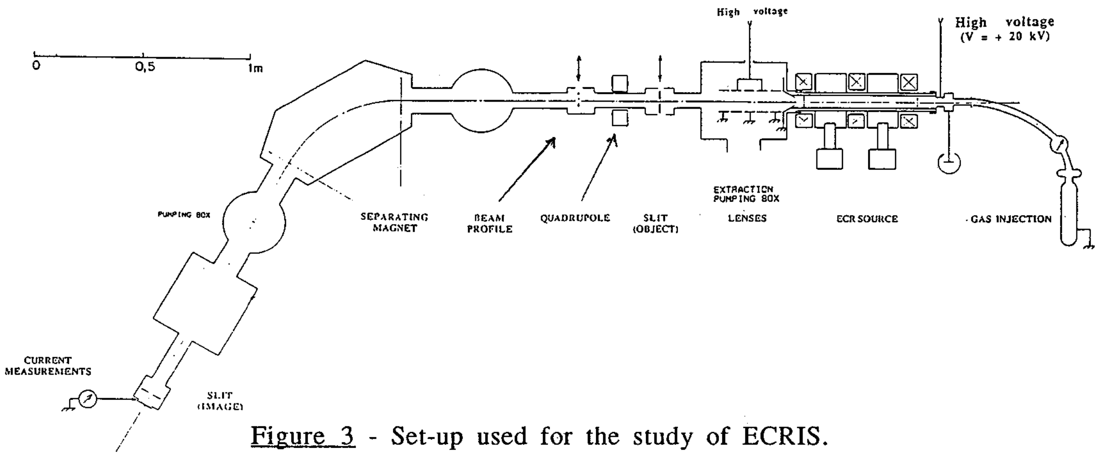

Figure 3 - Set-up used for the study of ECRIS.

the extraction system. Typical pressures of a few 10^{-6} torr at the extraction lead to the best performances for the singly-charged ion production. Indeed, at such a pressure, the beam can be well focalized, approximately 4 mm in diameter, and if wanted, used as a good object in front of a separating magnet.

Figure 3 is a plan view showing the experimental arrangement which has been used to test ion beam characteristics of the source, such as production, focalization, charges .... The repartition of the charges observed at the collector of the 60° magnet for argon or xenon ions in several measurements demonstrates the capability of this ECR ion source for singly-charged ion production $\left(I(Xe^{+}) / I(Xe^{++}) \geq 98\ \%\right)$. Typically, 1 mA total current of Ar^{+} or Xe^{+} ions can be easily measured at the collection site.

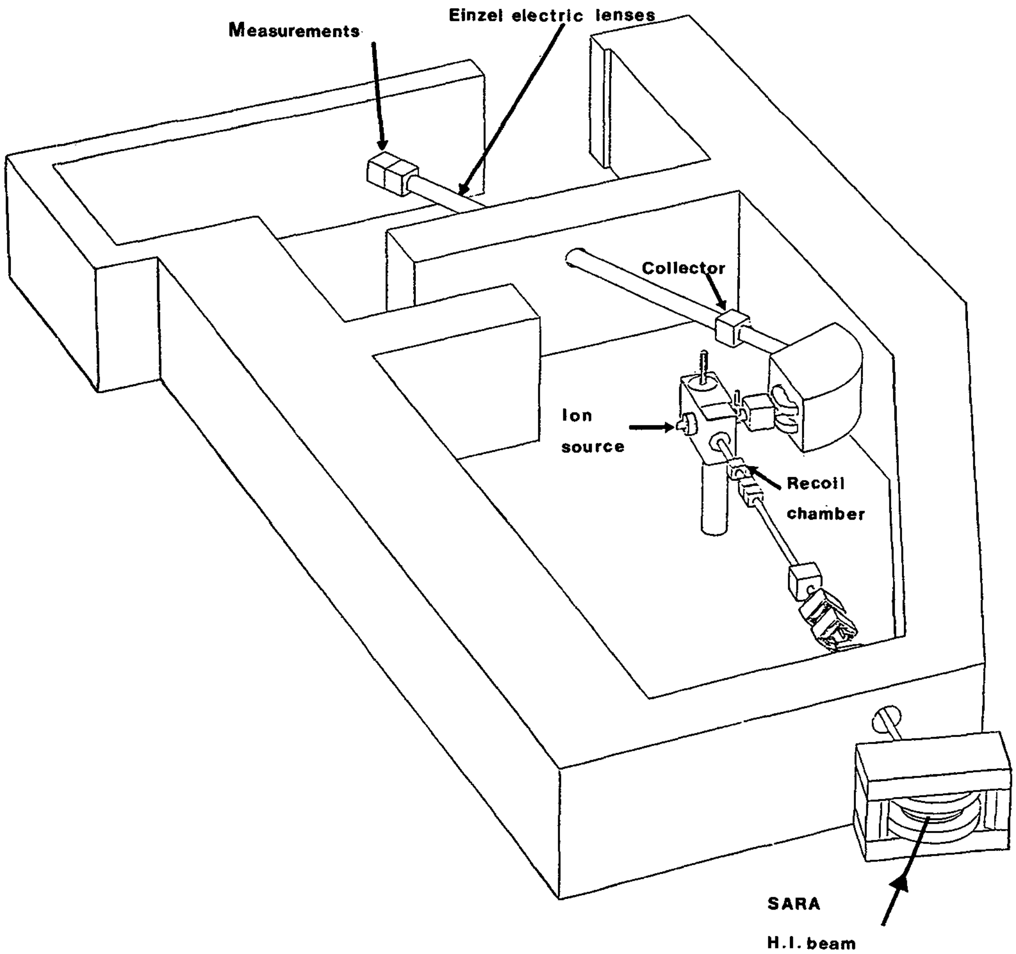

Figure 4 - The 120° on-line isotope separator at SARA.

Although precise absolute efficiency measurements have not been made, from mean estimated flux gas injection values (less than 0.05 $cm^3 . min^{-1}$) better than 20 % have been reached, which confirms the Geller's predictions /3/.

After these first promizing tests and taking in mind that the final aim is to use the ECR ion-source at the SARA on-line isotope separator a series of tests has been undertaken on this more dispersive set-up (figure 4). Using the magnetic field maps of the corresponding 120° analyzing magnet, sets for optics have been calculated with

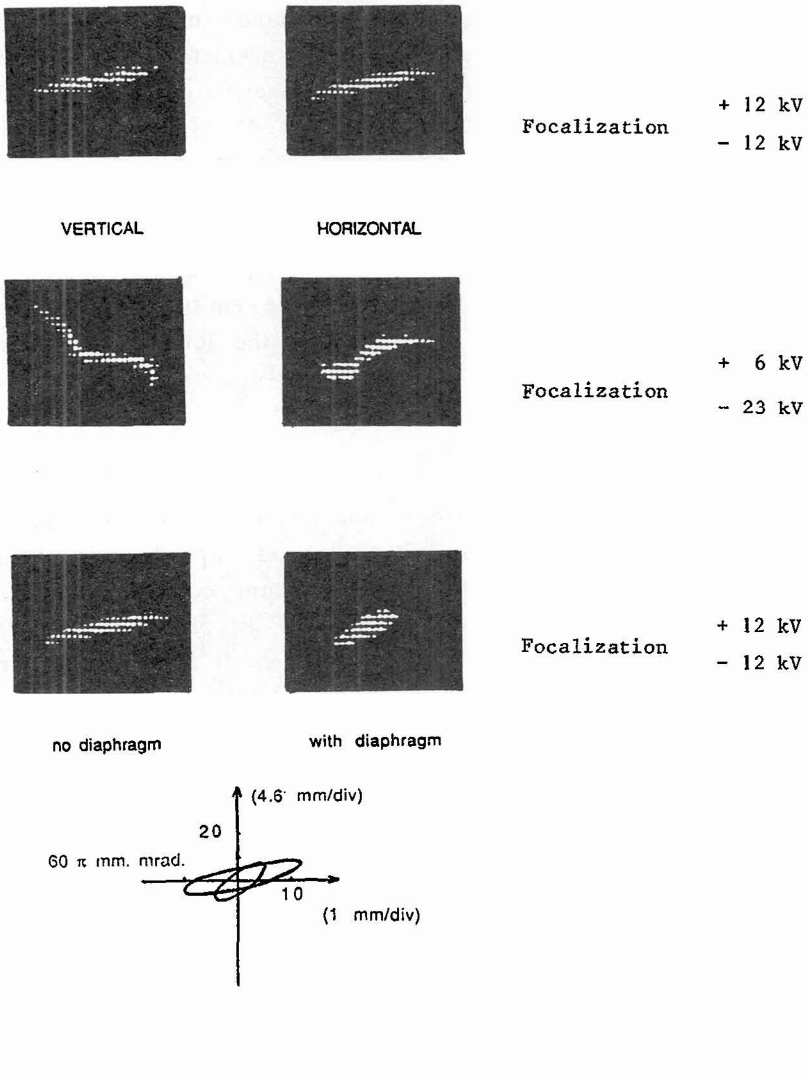

Figure 5 - Example of emittance measurements. Parameters at ECR are the same, except those of the focalization. The scale is given on the additional drawing which reproduces the variation by insertion of a slit.

the code TRANSPORT and by integration of the mouvement in the magnetic field /4/. When the extracted ion beam was focalized on a diaphragm (4 to 6 mm in diameter) by analogy with the method previously used with the 60° magnet, no final image and no correct separation were achieved. For 0.5 mA beam intensity, acceptable performances were obtained with an effective object of 20 mm in diameter in front of the magnet (not 6 mm as predicted by the calculations). Moreover, the experimental tests for optics agree quite well with the calculated ones only for weak beam intensities.

All these phenomena indicate that the space charge effects play an important role and that optical control and resolution adjustment appear very critical. As more detailed studies were needed, complementary emittance measurements have been undertaken on the 60° analyzing magnet. The emittancemeter can be placed at the entrance beam line or at the collector of the set up shown in figure 2. Emittances of the order of 60 π mm. mrad have been measured for Ar^+ ions. Unfortunately, with nearly the same parameters at the ion source one can observe that the situation is very complex as shown from the series of measurements reported in figure 5. In addition, the decisive role of the geometry at the extraction and of any inserted diaphragm along the beam have been clearly observed. During experiments, simply eyeing, one sees that the beam is modified by the emittancemeter itself ! It is important to mention that for variable parameters at the ion-source, "hollow" beams have also been observed.

3 - DISCUSSION

Up to now, from qualitative experimental results it appears very difficult to compensate the charge space effects with a good reproduction. The electron production is coming from the residual gas (vacuum conditions) and from the secondary emission i. e. from nature and position of all pieces in contact with the beam such as emittancemeter, grids, slits, diaphragms ... It appears that the electrons are caught in a potential well depending upon geometries, polarization of guide elements, shape of the space surrounding the beam (integration of the field $\vec{E}$ due to the electric charges between these charges and the grounded envelope depends upon the environment) [see. ref. /5/]. Consequently the energy distribution of ions in this potential well is probably partly responsible of separation lacks of the analyzing magnet. The correlated observations at various places along the beam trajectories seem indicate that the secondary e^- caught inside the well can go back along the beam, through the magnet, oscillating vertically but always trapped by the beam. In order to achieve the acceptable experimental conditions for on-line isotopic separation, mechanical and vacuum improvements of the entrance beam line of the 120° analyzing magnet are under construction. They will permit a more precise study of the ECR ion-source, with a maximum of flexibility.

In the presence of charge space difficulties, we want to work with gas mixings such as Xe plus Ar or He, at various percentages, and try to eliminate as far as possible the gas support. These conditions will simulate the future He-jet on-line experiments where the radioactive ions will represent a very weak part with respect to the ions coming from the gas support.

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